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quality evaluation procedures for research and food industry applications in East and Central Africa

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Cover photo: crisps for fry colour determination using a colour chart and (inset) potato chips ready for processing

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Foreword

This bulletin is based on a 5-year study on promotion of potato processing in Regional Network for Improvement of Potato and Sweetpotato (PRAPACE) member countries. The procedures herein arose out of the need to improve the quality of potatoes in the highland regions of East and Central Africa. Furthermore, there was need for low-cost laboratory methods to aid in the development of superior processing potato varieties, mainly for potato chips (French fries), now an important food in urban areas, and potato crisps, a popular snack food product in the region.

The bulletin will be useful in aiding routine quality analyses of potatoes under simple laboratory conditions. It will also be invaluable for practical training in food technology for undergraduate students. The authors have made an attempt to explain the requirements needed in improving the quality of potato tubers for processing. They have also outlined the production process for potato chips and crisps for the benefit of the reader, before embarking on simple methods for laboratory examination of tuber qualities. These procedures will serve as a good starting point for food technologists looking for laboratory techniques for research or routine quality evaluations in research stations and food industries involved in potato processing within East and Central Africa. The Kenya Agricultural Research Institute (KARI) and the International Potato Centre (CIP) are proud to be associated with the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA), which has facilitated PRAPACE to make such information available for use by a wide array of professionals in the further development of the potato industry in the region.

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Introduction

Agricultural research and extension efforts in sub-Saharan Africa have resulted in development of potato varieties with higher yields and resistance to pests and diseases. However, inadequate attention to appropriate postharvest handling, storage and processing to make potatoes available throughout the year at a price consumers can afford is a major drawback to further development of the crop. Development and support for commercial-level potato processing is one approach through which marketing constraints can be alleviated. Processing has potential for enabling potato achieve an industrial-level status similar to that of maize and wheat. This would help to create more employment, improve nutrition and enhance incomes for potato farmers. In addition to using fresh potatoes for home consumption, the crop can be processed into a range of value-added products such as crisps, various snack food items, French fries, dried products such as flakes, and convenience products such as pre-peeled potatoes.

In order for farmers to produce potatoes for processing, it is necessary for the potato industry to come up with good quality raw materials. This manual gives an insight into quality requirements during production and storage of potatoes for processing. Simple laboratory methods for determination of potato quality are described. The information will be useful to researchers involved in development and improvement of varieties, food technologists and food industry managers involved in quality control and new product developments.

Determining potato quality

Quality means different things according to the purpose for which the potatoes are used. Quality may not exist as such but can be an agreement between farmers, traders and processors regarding which criteria to use during production, marketing or processing. The first impression of a food product can also constitute quality and is given by its appearance (colour, size and defects) which may determine the visual attractiveness of finished products. Colour of finish-fried potatoes and that of the partly fried products is also important. Organoleptic aspects such as texture ('mouth feel') and flavour of finished products are also relevant for no consumer would like to purchase oily or soggy French fries. On the other hand, consumers would not like to eat products that are bitter as a result of excessive levels of toxic compounds inherent in some cultivars. There may also be need to incorporate nutritional data such as the levels of amino acids, vitamins and minerals. Excessive sprouting and tuber greening may detract the normal appearance of tubers, resulting in low marketability. Quality of fresh and processed potatoes can be evaluated by both subjective and objective techniques. Most quality aspects can only be measured through sensory evaluation although instrumental methods are recommended.

Subjective methods

This method is based on the opinions of investigators who are required to go through a mental process in characterising the product. The researcher who develops a variety or food product is the first one to make some sensory evaluation of the product.

In sensory evaluation, the product is tested for taste, colour, texture, smell, touch and crunching (sound produced when eating). Sensory evaluation of 10-20 panelists test 3 or 4 replications of cooked and processed products. Because of the variability in results of sensory tests, interpretation cannot be made by direct examination of the data. The results are analysed by statistical methods such as scoring or ranking and expressed in degrees of significance, which is the probability that the results are caused by chance. After laboratory screening, it is recommended that the products are assessed for consumer acceptability which would in turn determine need for improvement before marketing.

Objective methods

These methods are based on observations from which the attitudes of investigators are entirely excluded. The measurements are based on standard scientific tests and are applicable to any sample of the product without regard to its previous history or ultimate use. Such methods represent the modern idea in quality control because the human element has been excluded. The methods are divided in to three categories: physical methods (dry matter content, fry colour and others which could be evaluated using instruments); chemical methods used in standard food analysis to determine nutritive and quality levels (ascorbic acid, reducing sugars, etc) and microscopic techniques (for examination of spoilage bacteria and fungi in processed products). Only physical methods will be considered further due to the ease with which appropriate laboratory capability can be set up inexpensively.

Tuber quality aspects

There are two important parameters that are used to determine tuber quality for processing, external and internal aspects.

External qualities

Appearance (size, shape and shallow eyes) influences the wastage that occurs during peeling. Other aspects are occurrence of diseases on the skin, and the extent to which external damage has occurred. The desired tuber sizes depend on the type of product required. Long or long oval tubers larger than 50 mm are ideal for preparing French fries while round oval tubers between 40 and 60 mm are ideal for preparing crisps. Processing of crisps from tubers larger than 60 mm would expose the large slices to damage after packaging. Tuber size is influenced by cultural practices, while shape and eye-depth are varietal characteristics. Any shape irregularities may be a result of secondary growth. Since deep eyes result in higher peeling losses, varieties with shallow eyes are most preferred for processing. The tubers of a good sample of round or oblong tubers could weigh between 200 and 300 g while larger tubers of up to 500 g

are acceptable for preparation of French fries but not for crisps. Tuber sizes for manufacture of French fries will vary depending on the size of the package. Small tubers are desirable for packaging in small bags. Shape of the tubers is significant to the processors of crisps and French fries since it affects peel loss or recovery. Absence of defects such as diseased potatoes with rot, sprouts or greening minimises loss when trimming and results in uniformity of the processed product. Tubers with defects will result in defects in poor quality finished products.

Processors and consumers often associate quality of a product with tuber colour. Kerr's Pink, for example, an old Kenyan variety is round deep-eyed and is pale purple. It fetches premium prices due to its high quality tubers despite its susceptibility to late blight. This has discouraged introduction and promotion of newer cultivars for processing that do not have a pink skin.

If potatoes are exposed to light, they develop chlorophyll, the green colouring matter in plants that detracts from the normal appearance of ware potatoes. This can happen when tubers are washed and exposed for sale in the supermarket or placed in a heap (without covering) during retail marketing. It can also happen if tubers are insufficiently covered with soil during ridging. Greened potatoes are unfit for consumption because of the high content of toxic glycoalkaloids which build up beneath the surface of the skin. In most of the region, potatoes for processing are sold mainly by retailers. In order to prevent greening and the light-induced accumulation of glycoalkaloids, the following should also be observed for tubers meant for processing:

- They should be harvested when fully mature
- Discard sun-burned tubers
- Avoid bruising or skinning of tubers
- Store potatoes in dark and cool places

Internal qualities

The internal qualities include dry matter content, sugar content and discoloration in cut tubers and processed products. Profitability and consumer appeal are influenced greatly by these qualities.

Dry matter content. If the dry matter content is too low, the French fries or crisps will be too soft or too wet and will need more heat to fry in order to evaporate the water. If the dry matter content is too high, the finished products will be too hard and dry. The dry matter content partly determines the texture and oiliness of the finished products, thus determining consumer preference. Potatoes with a dry matter content of 20-24% are ideal for making French fries while those with a dry matter content of up to 24% are ideal for preparing crisps. Since some dry matter is lost during peeling, trimming, slicing and blanching, the higher the initial content, the higher the amount that remains after frying.

Reducing sugar content. The reducing sugar content in raw potatoes largely influences the colour of the fried products. The higher the content of reducing sugars, the darker the frying colour which is an important quality criterion for

French fries and potato crisps. The darker products are usually bitter, both qualities are unacceptable by consumers. Potato crisps make the highest demands on content of reducing sugars, which should not be more than 0.2-3.0% of the fresh weight. For French fries, the reducing sugar could be up to 0.5% of the fresh weight.

Enzymatic browning. This type of discoloration occurs when cut, sliced and bruised tubers are exposed to air for some time. It is caused by the oxidation of phenolic compounds by the enzyme phenolase. The enzyme phenolase has two major substrates in potato—chlorogenic acid and the amino acid tyrosine. Level of browning depends on cultivar.

After-cooking blackening. This defect shows up only after the tubers have been boiled, steamed, frozen or canned and also occurs in dehydrated potatoes. The effects are more pronounced in susceptible varieties. It is not confined to any one variety or cultural condition, although both are important. This discoloration occurs in tubers grown in most parts of the world.

Improvement of tuber quality

The quality of processed French fries and crisps depends on raw materials used (potato tubers, fat, salt and packaging) and methods of processing including the unit operations and their control. The raw product determines in great part the quality of the finished processed product. Production of good raw material, good processing output and ultimately a good end product depend on variety or cultivar, cultural care, and harvest and postharvest handling including storage and processing conditions.

Selection of processing varieties

Some varieties are not suitable for manufacture of processed products. It is important for researchers to recommend to growers only those varieties that make good quality products both at harvest and after storage for various periods of time. Some cultivars are unsuitable for processing directly from the field due to low specific gravity of less than 1.070, high reducing sugar content of more than 0.2-0.3% or high levels of toxic glycoalkaloids of more than 20 mg/100 g fresh weight. Others include large tubers of more than 80 mm or small tubers of less than 40 mm, misshapen tubers or excess defects (hollow heart, greening, sprout growth, tuber moth damage etc). Furthermore, after sometime in storage, other cultivars are inferior because of one or more of the reasons given above.

Cultivation practices

Crop husbandry practices including fertilisation, ridging, weeding, pest and disease control and, the time and method of harvesting influence the quality of processing potatoes. Soil should be analysed to determine fertiliser requirements. Too low potassium, for example, causes grey discoloration of French fries after blanching and pre-frying while high dosages of nitrogen fertiliser leads to faster growth that causes growth cracks and hollow hearts. Fertiliser application and other recommended practices after soil analysis result in steady and continuous growth that improves tuber quality.

Many bacterial, fungal and viral diseases are seed-borne and cause defects in raw potatoes and their products. Diseases result in loss when peeling and trimming, and may give unwanted colour variations to processed products. The most important diseases are wilts and rots while potato tuber moth (PTM) damage stored potatoes. Pests and diseases including late blight, soft rots and PTM should be controlled during growth and in storage.

Harvesting and postharvest handling

Potatoes reach full maturity when the tops of plants become withered. Although tubers of acceptable size may be harvested for immediate use, only fully mature potatoes should be stored. Mature tubers have optimum levels of dry matter content necessary for high yields, good consumer appeal and result in good texture and low oil content in processed products. Fully mature tubers also suffer less from harvest and transport damage and are easier to handle during processing.

Potatoes are generally ready for harvesting as soon as the skin of the tubers is firm (thumb test) and the connections between the stem and the tubers are sufficiently loose. Haulms (tops) should be removed 14 days before harvesting to allow the skin to harden and reduce damage at harvest. In order to reduce damage and maintain tuber quality, the following rules should be adhered to during and after harvest:

- The tubers should be covered with soil after removing the tops to prevent light turning the tubers green and PTM from laying eggs on the tubers.
- Carefully move the jembe or fork across the ridge to remove the tubers. Never dig directly into a ridge to avoid damaging tubers.
- Remove injured and rotten tubers and, stones and lumps of soil (**Plate 1**).
- Handling easily gives rise to damage underneath the skin. Harvest and handling should be as careful as possible to minimise tuber damage.

Plate 1. Potato tubers should be harvested and sorted carefully to avoid damage

After harvesting, the potatoes should be given sufficient time to suberise (harden the skin and heal minor injuries). The hardened skin protects the potato tuber from excessive loss of water and against micro-organisms which cause tuber rots. This process takes 10-12 days under a temperature of 15-20°C and a high relative humidity of 90%. No wound healing occurs below 5°C.

The grading of tubers is an important handling step in preparation of potatoes for marketing, storage and processing. Depending on local circumstances, tubers to be graded may be removed from the farm or storage in bags or crates. The grading process includes the following activities:

- Removal of foreign matter such as loose soil and soil clods
- Removal of sub-standard tubers such as those diseased, affected by greening, damaged by PTM or damaged during harvest or in storage.
- Removal of small tubers (less than 40 mm) and big tubers (more than 80 mm).
- Weighing and packaging.

Other operations such as washing, brushing and peeling may be carried out in the case of pre-peeled potato business. Tubers for sale in supermarkets may also need to be washed during grading. Tubers which have sprouted excessively (and lost more than 10% of the initial weight) are soft and difficult to handle during pre-processing (peeling, cutting, etc) and should be sorted out during grading.

Storage procedures

Immediate need for cash drives many farmers to harvest early and sell their potatoes at low prices. Market prices improve after 2-3 months, implying that there is need to improve storage to bridge the supply gap between harvests, steady prices and ensure food security. This could also encourage investments by the private sector and individual farmers. Storage should be low-cost using normal ambient (outside) air circulation. Low-cost potato stores in highland areas can be constructed using locally available materials for holding processing potatoes for up to 10 weeks. These stores could use cooler night ambient air with provision for fan ventilation to improve airflow rates through potato heaps, bags or crates. The floors could have wooden slats with airflow ducts for ventilation while insulation using wood panels on the sides and the ceiling improves retention of cool night air. Stone chambers could be provisioned with electric fans for improved air flow through potato heaps.

A stone construction is durable but more expensive than timber. However, the most important thing is type of low-cost local materials and the possibility of using night air for cooling the potatoes.

A study of ambient air temperature and humidity characteristics should be done to determine whether outside air-cooling needs to be supplemented with a fan, the number of hours for cooling at night, and the lowest and highest temperatures. Such knowledge can be obtained from a study of long-term weather patterns (Table 1).

Table 1. Mean long-term ambient air temperature (°C), rainfall (mm) and relative humidity (%) at Tigoni (1983-2001) [1, 2, 3]

Ambient air	J	F	M	A	M	J	J	A	S	O	N	D
Temp	18.4	18.9	19.1	17.7	16.9	16.3	14.5	15.0	16.4	17.6	17.4	16.5
RF	66	63	127	327	308	64	39	48	25	95	271	128
RH	80.0	77.0	71.2	80.1	84.0	81.5	80.9	81.2	80.0	80.8	81.9	81.4

[1]—Main potato harvests: February/March and August/September
[2]—Proposed storage period for processing potatoes: March-July and September-January
[3]—Long term means 1983-2001:Temperature (°C): 16.5 (December)- 17.4 (November); RF rainfall; Relative humidity (RH [%]): 81.4 (December)-81.9 (November)

Simple rules to improve storability

The total loss of weight in storage is mainly caused by evaporation and sprouting (about 90%), and respiration (about 10%). Other factors include duration of storage, temperature, relative humidity, quality of tubers, pests and diseases, storability of variety, and the system of storage. Using the naturally ventilated store, however, most varieties can keep for up to 6-8 weeks before sprout losses become excessive (**Plate 2**).

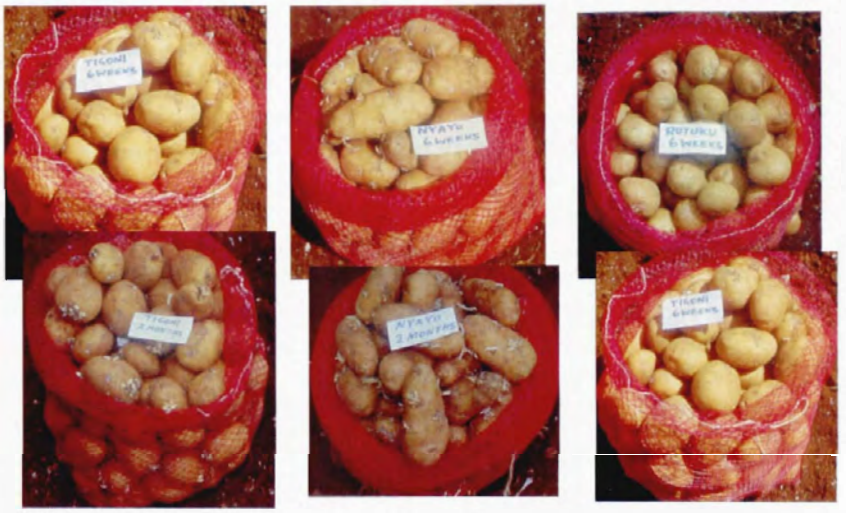


Plate 2. Storage period affects sprout growth and shrinkage in processing varieties

Storage does not improve tuber quality. Potatoes for storage should have as little damage as possible and should have no disease and pest damage. To maintain tuber quality, the following rules should be adhered to during storage:

- Use specially designed potato stores such as that described above.
- Potatoes should be stored in the dark to prevent tuber greening.
- Do not store wet potatoes to prevent tuber rotting and premature sprouting.

- Potatoes should be placed in open wooden boxes with gaps in the bottom and side planks to allow ventilation, and not in sacks. The boxes should be 25-30 cm above the floor. The crates should be covered with loose dry grass or straw. If heaps are of more than 500 kg, an air duct should be placed in the heap to allow for ventilation (**Plate 3**).

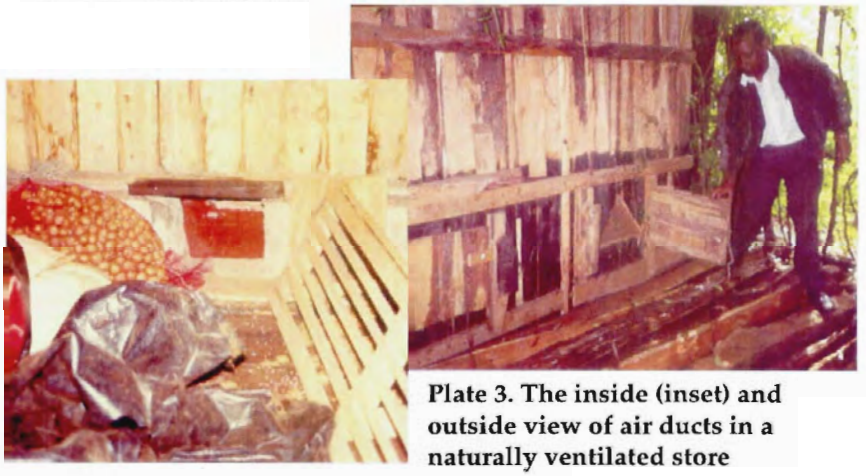


Plate 3. The inside (inset) and outside view of air ducts in a naturally ventilated store

- Storage in simple stores is most ideal in cool night air temperatures of not more than 14°C, mostly found at altitudes higher than 1800 m above sea level.
- If the store is ventilated during the night, the air is moister as well as cooler, and this is the best time to cool the potatoes. Do not leave the doors or ventilation open during the day when it is dry and hot.
- The high temperature in stores should be maintained for 14 days to cure injuries.
- Once tubers are in permanent storage and curing is completed, cool temperatures and moist conditions should be encouraged.

Processing procedures

Determine specific gravity on duplicate samples of tubers and carry out a laboratory examination for quality of French fries and crisps. A laboratory assessment of processing quality after 8-12 weeks in storage would show whether the cultivars are good for processing or not particularly if the weight losses are less than 10% (fresh weight basis) and the fried products are light brown. A test can be conducted on partly fried (or blanched) French fries or on cooked tubers to check on after-cooking blackening.

Potato tubers can be peeled by hand or mechanically, then sliced on manual or mechanical slicers before being fried in wire baskets immersed in open kettles of hot oil or in electric fryers. These batch operations have a high demand of manual labour, which could be suitable for small-scale processing of both

French fries and crisps. For production of large volumes, however, automatic and semi-automatic equipment is necessary.

Waste from peeling, slicing and washing contain starch which has commercial value. This, together with small potatoes may be used as animal feed. Greened and sprouted tubers could be sold or planted. Otherwise, effluent from processing should be handled according to local public health regulations. Processors should also ensure that finished products meet standard microbiological standards for the health of consumers. The following are recommended procedures for production of processed potato products (Fig. 1).

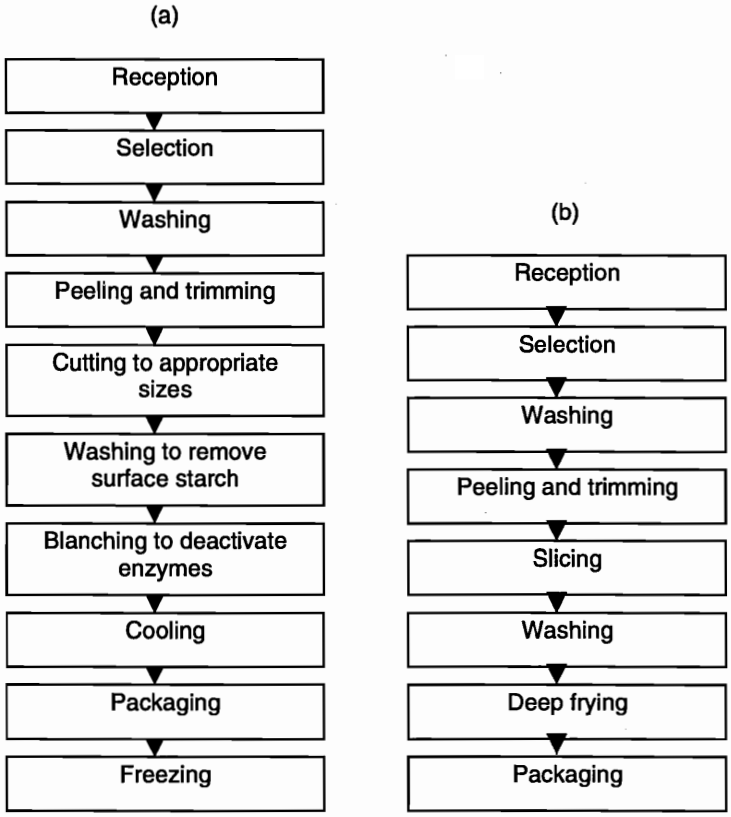


Fig. 1. Stages for production of French fries (a) and potato crisps (b)

Receiving and cleaning potatoes

Potatoes are mainly received from storage within the processing facility or from suppliers and farmers who deliver truckloads in bags and crates to factories. For research purposes, breeders harvest and provide appropriate samples for trials at laboratories. At this point, green, misshapen, excessively sprouting and rotten, mechanically damaged and tubers infested by PTM should be removed. In continuous plant operations, the tubers are conveyed along an inspection belt where defective tubers are removed by hand.

Washing

Inspecting clean potatoes makes detection of defects easier. Dirty potatoes should be washed to remove soil, insects, sprouts and other foreign matter. Small amounts of soil can be removed during peeling. Following a wet harvest, the tubers may have high soil content and washing is essential. Washing can be done using a hose pipe or using a manually operated washer.

Peeling and trimming

The yield of French fries and crisps is governed mainly by peeling, trimming and cutting methods and the size and shape of potatoes.

Peeling may be by machine or manually (**Plates 4 and 5**). Machine peeling operates by rubbing tubers around a (rough) carborundum surface. The disadvantage of this method is the increased peeling losses and the difficulty to peel unevenly shaped tubers. For crisps, however, small pieces of skin can be acceptable in the finished product. Peeling losses are between 10 and 15% and depend on the efficiency of the equipment, size and shape of potatoes, depth of eyes and depth of peeling. Peeled and washed potatoes are inspected to remove sub-standard tubers, while those with minor (visible) defects are trimmed.

Plates 4 and 5. Peeling by machine and by hand using knives

Cutting or slicing

Making potato sticks for French fries or slices for crisps can be done by hand but larger operations need electric cutting machines. When cutting potatoes for French fries, it is preferable to cut the tubers lengthwise to obtain maximum long sticks with minimum losses. Strips that are shorter than 30 mm should be

removed and can be used for mashed potatoes or as animal feed. They should be 5 x 5 mm, 10 x 10 mm or 12 x 12 mm depending on consumer preferences. For crisps, the slice thickness may be varied between 1.2 and 2.0 mm. Thicker slices absorb less oil as oil mainly 'sits' at the surface of the crisps (with less surface area) resulting in less oil on the crisps.

Washing and drying

Surface starch and other materials that come out of cut potato cells cause the products to stick together and to cook and colour unevenly. They should be removed by washing using water and drying using cloth towels in small operations and by mechanical de-watering in larger operations. It is important to remove as much of the wash water as possible from the slices or sticks before drying.

Blanching

Hot water blanching at 65-100°C before frying destroys enzyme activity and leaches out, reducing sugars and other chemical constituents that cause off-colour and off flavour. French fry strips should be water-blanched before frying in order to:

- produce a more uniform colour of fried products
- reduce absorption of fat through gelatinisation of the surface layer of starch
- reduce frying time since the potato is partially cooked by blanching
- improve texture of final product

Blanching of French fries inactivates the polyphenoloxidase enzyme, a result of which enzymatic discoloration in par-fried products is avoided. The non-enzymatic browning through the reaction of reducing sugars and nitrogen is avoided through blanching (**Plate 6**). The non-enzymatic grey (after-cooking) discoloration can be prevented in the blanching process by adding acid-sodium pyrophosphate. The chemical forms a colourless compound with ferrous ions in the potato thus preventing the formation of the grey colouration between chlorogenic acid and ferrous ions. It is added to the blanching water or as a dip after the blanching process. The blanching also influences texture of French fries. It contributes somewhat towards the cooking process of the French fries contributing to a firm texture which facilities further handling. Blanch water may be re-used in order to minimise excessive leaching out of important flavour compounds from the potato. Excess moisture on the surface of the strips should be removed to before frying.

Plate 6. Blanching machine

Potatoes for crisping should not be water-blanched to prevent excessive loss of flavour. Tubers should be selected carefully to have only those with low sugar levels. A preliminary dry test on samples of processing tubers can be conducted to select processing tubers. The slices should, however, be washed to remove starch from the surface which is caused by slicing damage.

Par-frying

Evaporation of water from cut surfaces before deep-frying gives French fries their characteristic crispy exterior. The temperature of the fat in the fryer should be 135-190°C but higher temperatures fry faster. Par-frying should be for between 30 s and 6 min depending on the type of product. Deep frozen products fry for a shorter time than fresh French fries. The inside of French fries is cooked when the exterior becomes crispy. French fries should be deep-fried in fat that is solid at room temperature. As crisps are eaten at room temperature, the solid fat would give them a granular texture. They are therefore fried in liquid oil. A laboratory chest freezer is ideal for small commercial operations.

Cooling and freezing

After frying and removing superficial fat, the product should be cooled and, where necessary, deep-frozen within 20 min at -18 to -20°C in order to retain texture and to avoid damage as a result of ice crystal formation. A laboratory chest freezer is ideal for small commercial operations.

Quality control procedures

Just before processing, it is necessary to select specific lots of potatoes and check for processing quality by conducting laboratory-scale preparation and frying test. It is then possible to control product quality through records of the raw material and that of finished product at the different stages of processing. The food researcher is encouraged to conduct pilot-scale production whereby factory-level quality control protocols could be simulated. To achieve consistent quality products, processing must be carried out under controlled hygienic conditions and in a specified sequence of operations. Process control is required on all materials, production processes and equipment used for manufacturing. All of the following points must be considered:

- Raw materials
  - Tubers: size, shape, defects, dry matter content, sugar content.
  - Fats/oils: suitability for frying crisps or French fries.
  - Salts and seasoning.
- Processing operations
  - Peeling and trimming: inspection for degree of peeling and trimming, checks for losses; waste disposal.
  - Washing: recovery of starch.
  - Slicing/cutting: measurement of slice/strip thickness; adjustment of cutting blades.
  - Blanching of French fries: temperature control; adequacy of blanching.

- Frying stage: check time and temperature controls of fryer; examine frying oil and fat for burnt particles, off-flavour; filter oils; check equipment for proper operation.

- Finished products
  - Inspection for appearance, colour (post-cooking discoloration), flavour (off-flavour): size of French fries sticks.
  - Measurements: moisture content, keeping quality; sensory quality (colour, texture, defects; bitterness; oiliness).
  - Packaging: check weight of different products and note any weight shortage; be alert to employees who could be handling the finished product with dirty hands.

Quality evaluation procedures

Specific lots of potatoes are checked for processing quality by conducting laboratory scale preparation and frying tests. A checklist for initial selection of processing potatoes is given in Table 2.

Table 2. Check list for the processing tuber quality requirements

Quality characteristic	French fries	Crisps
Tuber shape	Long/oval tubers	Round/oval tubers
Eye depth	Shallow eyes	Shallow eyes
Tuber defects	Few defects	Few defects
Presence of greening	No greening	No greening
Sprout growth	Little or no sprout growth	Little or no sprout growth
Appearance	Good appearance	Good appearance
Dry matter content	High DM (1.080 SG[1])	High DM (1.080 SG[1])
Tuber size	Big tubers: >50 mm	Big tubers: 40-60 mm

[1]Specific gravity; Dry matter content should be more than 20%

Determination of sprout growth and weight loss

Duplicate samples of about 18-20 kg are weighed and stored in the dark using ambient air for ventilation. The tubers should be in good condition and well-cured. They should be weighed every 14 days for 12 weeks. At each date, the number of sprouts for each tuber and weight are recorded. The tubers are desprouted at 12 weeks and the weight of both the tubers and sprouts recorded. The number or tubers diseased with (rot) and those with PTM are also recorded.

Peel and trimming losses

The test results indicate losses in a variety or lots of potato tubers and predicts the necessary degree of peeling in commercial operations. It also predicts the loss after trimming and shows physical defects including depth of eyes and tendency to greening in a lot of potatoes.

Procedure

A balance, plastic container and an abrasive peeler are used to carry out the test as follows:

- Weigh empty container
- Weigh representative 10 kg tubers in duplicate
- Peel
- Remove peeled potatoes
- Remove excess water
- Weigh peeled tubers
- Use a knife to trim to the desired degree
- Weigh peeled/trimmed tubers
- Calculate percentage peel loss as follows:

$$\frac{\text{Weight of peeled potatoes}}{\text{Weight of unpeeled potatoes} - \text{Weight of peeled potatoes}} \times 100$$

- Calculate percentage trimming loss as follows:

$$\frac{\text{Amount lost in trimming}}{\text{Weight of peeled potatoes}} \times 100$$

The peeling and trimming losses will vary with size and shape of potatoes, and peeling method but are usually up to 15-40%.

Dry matter content

Dry matter content is determined using an oven and balance accurate to 0.1 g.

Cut duplicates of 10 tubers into 1-2 cm pieces and mix thoroughly, taking two sub-samples of 200 g (fresh weight) each. All parts of the tuber should be sampled, as dry matter content is not uniform throughout.

Weigh and record the weight of each sub-sample, and place the samples in an open metal container or paper bag and set oven at 80°C. Dry for 72 h or until the weight is constant. Weigh the two samples after oven drying and calculate dry matter content on a percent basis (dry weight/fresh weight) x 100. Dry matter contents of more than 20% are acceptable.

Specific gravity

Specific gravity is a simple and convenient measurement of tuber dry matter content and is assessed using a balance with a capacity of 5 kg and an accuracy of one gramme, a metal basket or nylon mesh bags, and a water basin.

The specific gravity test is important to the potato processing industry since the dry matter content of the raw potatoes determines both the output and the quality of processed products (**Plates 7 and 8**). The cooking quality of potatoes is largely affected by the dry matter content. Potato tubers containing high

solid matter of up to 24% produce fried products with high yields, less oil absorption and having better texture than those with lower solids. The weight–in-air/weight-in-water (WIW) method is used to determine specific gravity as described below.

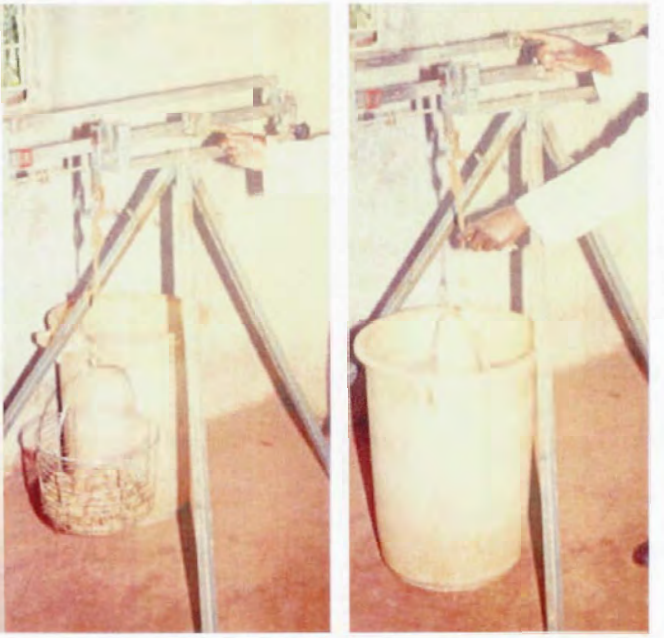
Duplicate samples of good quality ware sized potatoes is placed in a metal basket, weighed in air (5 kg) and again in cold tap water (x g).

In practice, the following limits can be used for under water weight: French fries ±400 (370-450) grammes; crisps ±430 (400-470) grammes.

Specific gravity can be calculated by using the following formula:

- $$\text{Specific gravity} = \frac{\text{Weight-in-air}}{\text{Weight-in-air - Weight in water}} = \frac{5000\ g}{5000\ g - x\ g}$$

Good quality potatoes should have a specific gravity value of more than 1.080. Potato tubers with specific gravity values less than 1.070 are generally unacceptable for processing.



Plates 7 and 8. Representative samples are weighed in air and in water to determine tuber specific gravity

Laboratory method for processing of fresh and deep frozen French fries

This test is designed to duplicate the commercial process for potato French fires. Tubers should be fully mature and well cured. Field tubers should be allowed to rest ('stabilise') at room temperature for 10-15 days after harvest.

The procedure for processing of fresh and deep frozen French fries (**Plates 9-12**) is outlined below.

- Select duplicate representative samples of 40 tubers each (with genetically uniform material, duplicates of 10 tubers per sample will suffice). Tubers should be free of disease and undamaged.
- Peel by hand or using an abrasive peeler.
- Cut tubers longitudinally into halves. Discard one tuber half and cut the other into 12 x 12 mm (sort out pieces less than 30 mm) sticks.
- Wash the sticks for 1-2 min in running tap water and dry superficially using a cloth towel.

Plates 9-12. Par-fried samples of French fries are weighed (top), packaged and deep frozen (bottom) for subsequent use in fry colour determination and sensory tests

- Pre-fry 200 g samples in fat of 150 ± 5°C for 4 min (use fresh frying fat when colour starts to turn brown). It may be necessary to fry each sample twice in rapid succession if the temperature drop is too high.
- Remove the sample from the fat, shake off adhering fat and allow the product to cool to room temperature.
- Fast freeze and store at -18°C or finish fry in fat at 180°C for 2 min (deep-frozen samples should not be thawed).
- Assess the colour of French fry samples using a modified Munsell colour card scoring system of 1 (very light) to 5 (very dark) or by using a laboratory sensory evaluation panel.

Laboratory method for processing of potato crisps

Field tubers should be allowed to rest ('stabilise') at room temperature for 10-15 days after harvest. They should be evaluated for the overall sensorial quality, and the degree of darkening during frying (using a colour chart). Potato slices should be fried at a constant temperature until the water content of the potato slices is below 2%. The procedure for production of potato crisps is outlined below.

- Select representative duplicate samples of at least 40 tubers each. When using clonal materials which are genetically uniform, 10 tubers per sample will suffice.
- Peel and trim.
- Slice into uniform slices, 1.2-1.3 mm thick (**Plate 13**).
- Wash for 1-2 min under running tap water to remove adhering starch.
- Dry superficially with a towel.
- Fry samples of 100 g each in duplicate in vegetable oil of 175 ± 5°C.
- Fry until the oil no longer bubbles, constantly stirring the oil bath to ensure

Plate 13. Slicing representative tuber samples for crisps and (inset) a chipping (French fries) machine

a uniform frying of all the slices.

- Remove crisps from the oil and drain by shaking the frying basket (use fresh oil when the golden yellow colour turns too brownish).
- Assess colour of finished products using methods such as Potato Chips/Snack Food Association (PC/SFA) colour card system of 1 to 5 where 1 (light cream) denotes low sugar levels (acceptable) and 5 (very dark brown) denotes very high sugar levels (highly unacceptable)

Sensorial evaluation of French fries

A trained sensory evaluation panel tests the overall quality of French fries. The reliability of the results depends on the evaluators recognising differences among the samples. The panelists should not eat or smoke for at least one hour before the tests. The most suitable hours for an evaluation are 10.00 in the morning and 02.00 in the afternoon. The characteristics to be analysed are colour, flavour, texture, uniformity of size and shape, and general appearance. A scoring scale of 1 (extremely poor) to 9 (extremely good) is used to assess the sensory quality of French fries (Table 3). Panel members receive a specific scoring table for each set of 8-10 samples. After completing frying (without allowing the frozen samples to thaw) in cooking fat, the samples are presented to panel members. Some of the specific qualities to be evaluated include—

- external appearance and external colour (scored on the whole sample while internal colour is obtained by breaking the fries and squeezing the oil to allow for visual examination)
- flesh texture (mealiness)

Table 3. Sensory evaluation score card

Please evaluate the samples for colour, texture, flavour and overall acceptability. Do not base your scores on a personal like or dislike for the product in general. Please do not communicate with anyone while scoring. Use numerical scores under the sample number in the scoring chart below

Acceptability	Quality description	Score
Unacceptability	Extremely poor	1
	Very poor	2
Barely acceptable	Poor	3
	Below fair/above poor	4
	Fair	5
Acceptable	Below good/above fair	6
	Good	7
	Very good	8
Highly acceptable	Extremely good	9

Sensory quality description

	Sample code										
Quality aspect	1	2	3	4	5	6	7	8	9	10	11
Colour (appearance)											
Texture											
Flavour											
Overall acceptability											

Name_____Date_____Signature_____

Determination of tuber cooking quality

A trained panel evaluates cooked tubers for acceptability for processing. The panel is trained to score the cooked tubers on a scale of 1-9 for colour, texture and flavour. Local varieties of good and poor cooking quality should be used as controls. Representative tubers are washed and cooked unpeeled without salt. They are then assessed while hot by a laboratory panel of not less than 10 judges. The combined judgement of the panelists minimises individual sensitivity variation or fluctuation through the day and from day to day. The following is the procedure followed before sensory evaluation:

- Select a representative sample consisting of at least 40 tubers (with clonal or genetically uniform materials, 10 tubers per clone may suffice). Tubers should be free of disease, undamaged and clean. A code is assigned to each entry and the relation recorded.
- Tubers are put in boiling water. They are ready when a fork penetrates the tuber. The average time needed for the stem and bud ends to cook is recorded.
- Keep the cooked potatoes hot by wrapping them in aluminium foil, ready for evaluation.
- Cut one tuber in half for each panelist for evaluation.
- Cooked tubers are presented to the panel on a plate and assessed.
- To assess post-cooking discoloration, place the potatoes on a white plate (or surface) and leave to cool overnight. Record the colour on a scale of 1 (intense black discoloration), 5 (sufficient discoloration to make the potatoes unacceptable) to 9 (no discoloration).

Potato varieties that discolor after cooking are not suitable for frozen French fries.

Excessive tissue disintegration, most pronounced in the outer region of the tuber results in 'sloughing' and is a textural defect in cooked potatoes. Mashing the potato with the back of a fork can be used to assess mealiness. A mealy potato is readily broken down to a dry floury (or crumbly) mash. Slight mealiness is usually required in potatoes with such tubers being suitable for mashing, crisps and French fries. Conversely, waxy (non-mealy) tubers are suitable for boiling whole, salad or canning while very mealy potatoes can be used for mashing only.

One special difficulty with assessing potato flavour is that texture differences tend to confuse flavour differences. Fortunately, pronounced bad flavours are usually found only when tubers are allowed to turn green or cultivars with excessive glycoalkaloid levels have been used in breeding programmes.

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